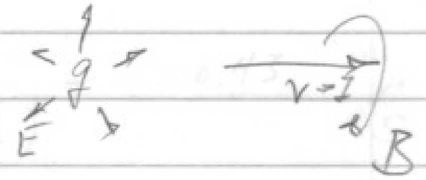
week 6 Physics of Astronomy Spring 2006 — HW due week 8 — E17 SOLNS

ELECTROMAGNETISM – after Workshop 27

Giancoli Ch 27 Q 17, 22, P 21, 25, 45, 52 p. 705
Ch 28 Q 4, 5, 7, 9, 12, P 1, 5, 11 p. 727
Ch 29 Q 2, 5, 7, 8, 10, P 3, 4, 7, 14 p. 750

Q (17.) What kind of field or fields surround a moving electric charge?



Q (22.) How could you tell whether moving electrons in a certain region of space are being deflected by an electric field or by a magnetic field (or by both)?

E ACCELERATES q in a straight line

B BENDS q without changing its speed

Combo of E & B can cause q to drift (E ↑, B ⊙) → drift

$KE = p^2/2m \rightarrow p^2 = 2mK$

P (21.) (II) A 5.0-MeV (kinetic energy) proton enters a 0.20-T field, in a plane perpendicular to the field. What is the radius of its path? = B

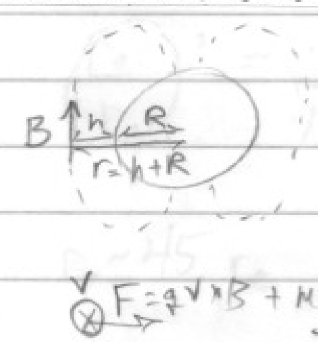
$F = ma$

$qvB = m\frac{v^2}{r} \rightarrow r = \frac{mv}{qB} = \frac{p}{qB} = \frac{\sqrt{2mK}}{qB}$

$r = \frac{\sqrt{2 \cdot 1.67\times10^{-27}\,kg \times 5\times10^{6}\,eV}}{1.6\times10^{-19}\,C \times 2\times10^{-1}\,(T = \frac{N s}{m C})} \left| \frac{1.6\times10^{-19}\,J}{eV} \right| = 1.6\ m$

P (25.) (II) Suppose the Earth's magnetic field at the equator has magnitude 0.40×10^{-4} T and a northerly direction at all points. How fast must a singly ionized uranium ion ($m = 238$ u, $q = e$) move so as to circle the Earth 5.0 km = h above the equator? Can you ignore gravity?

If $mg < qvB$ then $F = ma$ becomes $qvB = m\frac{v^2}{r}$



$r = h + R = 5\,km + 6.375\times10^{3}\,km = 6.38\times10^{3}\,m$

$v = \frac{qBr}{m} = \frac{1.6\times10^{-19}\,C \times 0.4\times10^{-4}\,T \times 6.38\times10^{6}\,m}{238 \times 1.67\times10^{-27}\,kg}$

$\vec{F} = q\vec{v}\times\vec{B} + m\vec{g}$

$v = 1.03\times10^{6}\ \frac{m}{s}$ relativistic! ($mg < qvB$ ✓)

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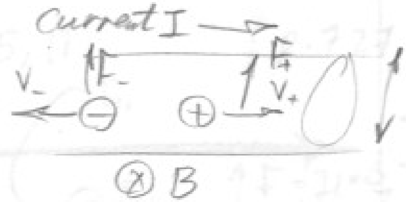
45. (II) The Hall effect can be used to measure blood flow rate because the blood contains ions that constitute an electric current. (*a*) Does the sign of the ions influence the emf? (*b*) Determine the flow velocity in an artery 3.3 mm $= l$ in diameter if the measured emf is 0.10 mV $= \mathcal{E}$ and B is $B =$ 0.070 T. (In actual practice, an alternating magnetic field is used.)



(a) Draw $\vec{F}_B = q\vec{v}\times\vec{B}$ on each charge. What is the direction of $\vec{E}$?

$F_E = F_B$: $qE = qvB$ YES: ⊕↑ but ⊖↑ : different emf ± depending on charge carrier

(b) $\mathcal{E}mf = El = vBl \rightarrow v = \mathcal{E}/Bl$

Speed $v = \dfrac{10^{-4}\text{ volts}}{3.3\times10^{-3}\text{ m}\ 7\times10^{-2}\ (T = \frac{\text{volt}\cdot s}{m^2})} = 0.43\ \dfrac{m}{s}$

52. A proton and an electron have the same kinetic energy upon entering a region of constant magnetic field. What is the ratio of the radii of their circular paths?

$K = \frac{1}{2}M_p v_p^2 = \frac{1}{2}m_e V_e^2$

$F = ma$

$qvB = m\dfrac{v^2}{r}$

$r = \dfrac{mv}{qB}$ - Note that q and B are the same

$$\frac{r_e}{r_p} = \frac{m_e V_e / qB}{m_p V_p / qB} = \frac{m_e V_e}{m_p V_p}$$

$$\left(\frac{r_e}{r_p}\right)^2 = \frac{(m_e V_e)^2}{(m_p V_p)^2} = \frac{\frac{1}{2}m_e V_e^2\ m_e}{\frac{1}{2}m_p V_p^2\ m_p} = \frac{K\ m_e}{K\ m_p} = \frac{m_e}{m_p}$$

$$\left(\frac{r_e}{r_p}\right)^2 \simeq \frac{.5\text{ MeV}}{1000\text{ MeV}} \simeq \frac{1}{2000}$$

$r_p \sim 45\ r_e$: proton cyclotron radius > electron cyclotron radius if they have the same energy

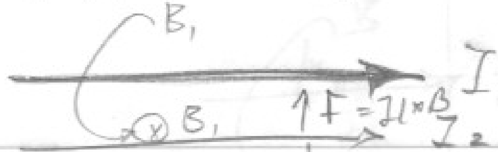
Ch 28 Q 4, 5, 7, 9, 12 P 1, 5, 11 p. 727

Q 4. A horizontal wire carries a large current. A second wire carrying a current in the same direction is suspended below. Can the current in the upper wire hold the lower wire in suspension against gravity? Under what conditions will it be in equilibrium? Find direction of F = Il×B,

5. A horizontal current-carrying wire, free to move in Earth's gravitational field, is suspended directly above a second, parallel, current-carrying wire. (*a*) In what direction is the current in the lower wire? (*b*) Can the upper wire be held in stable equilibrium due to the magnetic force of the lower wire? Explain.

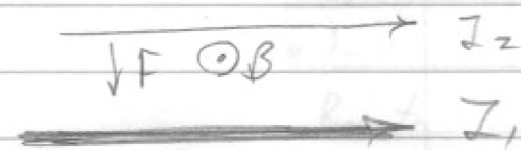
6. (*a*) Write Ampère's law for a path that surrounds both conductors in Fig. 28–8. (*b*) Repeat, assuming the lower current I_2, is in the opposite direction ($I_2 = -I_1$).

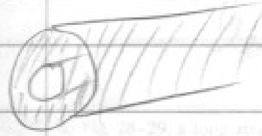
7. Suppose the cylindrical conductor of Fig. 28–9a has a concentric cylindrical hollow cavity inside it (so it looks like a pipe). What can you say about **B** in the cavity?



YES, if $IL \times B > F_g = mg$. NOT stable - a little pert and it will fall away.

STABLE EQUILIBRIUM - a little wobble and it will fall closer ✓





B=0 in cavity since I = 0 in cavity.
metal in cylinder = shield.

$\oint B \cdot dl = Bl = \mu_0 N I$ ← density of windings

$B = \mu_0 I B \left(\frac{N}{l}\right)$

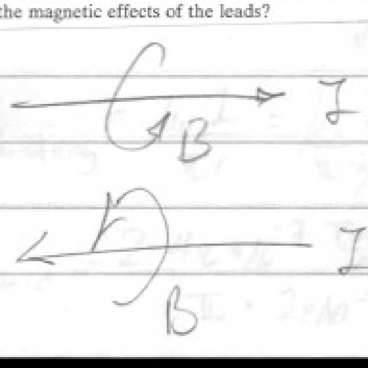
9. What would be the effect on *B* inside a long solenoid if (*a*) the diameter of all the loops was doubled, or (*b*) the spacing between loops was doubled, or (*c*) the solenoid's length was doubled along with a doubling in the total number of loops.

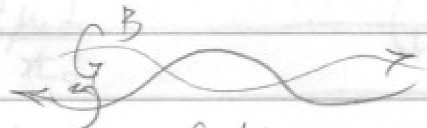
10. Use the Biot-Savart law to convince yourself that the field of the current loop in Fig. 28–18 is correct as shown for points off the axis.

11. Do you think **B** will be the same for all points in the plane of the current loop of Fig. 28–18?

12. Why does twisting the lead-in wires to electrical devices reduce the magnetic effects of the leads?

(a) no effect from diameter
(b) weaker if spacing is doubled - density of windings decreases
(c) no effect if winding density stays constant





B fields cancel, the more tightly wires are wound

Ch 28 P 1,5,11

1. (I) Jumper cables used to start a stalled vehicle often carry a 65-A current. How strong is the magnetic field 7.5 cm away? Compare to the Earth's magnetic field.

I = ; = r

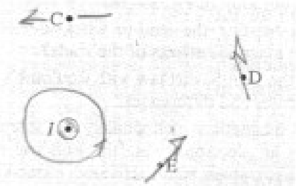
$$\oint B\cdot dl = \mu_0 I = B \cdot 2\pi r$$

$$B = \frac{\mu_0 I}{2\pi r} = \frac{(4\pi\times10^{-7}\,\frac{Tm}{A})(65\,A)}{2\pi(7.5\times10^{-2}\,m)}$$

$$B = 1.7\times10^{-4}\,T \sim 3\times B_{earth}$$

$$B_{earth} \sim \frac{1}{2}\times10^{-4}\,T$$

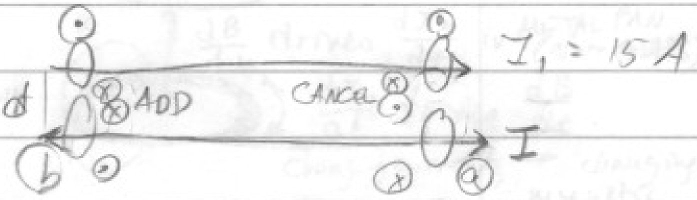
5. (I) In Fig. 28–29, a long straight wire carries current I out of the page toward the viewer. Indicate, with appropriate arrows, the direction of **B** at each of the points C, D, and E in the plane of the page.



#11 for $I \neq I_1$:

$$B_{mid} = \frac{\mu_0(15A \pm I)}{2\pi\, d/2} = 2\times10^{-5}\,\frac{T}{A}(15A \pm I)$$

11. (II) Determine the magnetic field midway between two long straight wires 2.0 cm apart in terms of the current I in one when the other carries 15 A. Assume these currents are (a) in the same direction, and (b) in opposite directions.

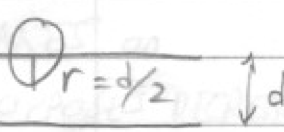


Find direction of $\bar{B}$ for each case. (a) Fields cancel: $B_{midway} = 0$

(b) Fields add: $B_{midway} = 2B$ where $\oint B\cdot dl = \mu_0 I = B\cdot 2\pi r$

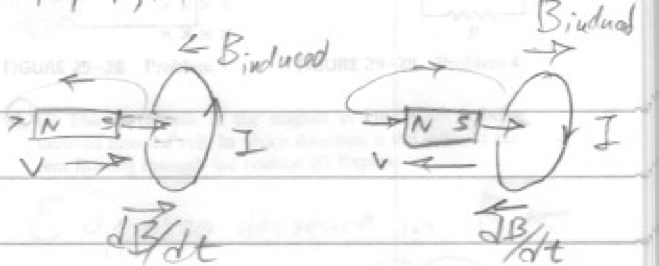
$$B = \mu_0 I / 2\pi r$$

$$B_{midway} = \frac{\mu_0 I}{\pi r} = \frac{\mu_0 I}{\pi\, d/2} = \frac{2\mu_0 I}{\pi d}$$



$$B_{mid} = \frac{2\times4\pi\times10^{-7}\,\frac{Tm}{A}\times15\,A}{\pi\times2\times10^{-2}\,m} = 4\times15\times10^{-7+2}\,T = 60\times10^{-5} = 6\times10^{-4}\,T$$

Ch 29 Q 2, 5, 7, 8, 10   P 3, 4, 7, 14



(2.) Suppose you are holding a circular loop of wire and suddenly thrust a magnet, south pole first, toward the center of the circle. Is a current induced in the wire? Is a current induced when the magnet is held steady within the loop? Is a current induced when you withdraw the magnet? In each case, if your answer is yes, specify the direction.

Current is induced ONLY WHEN MAGNET IS MOVING, in a direction to OPPOSE THE CHANGE IN MAGNETIC FLUX.

(5.) Two loops of wire are moving in the vicinity of a very long straight wire carrying a steady current as shown in Fig. 29–26. Find the direction of the induced current in each loop.

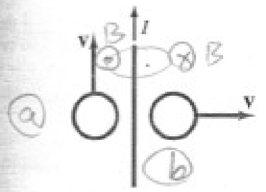


FIGURE 29–26
Question 5.

(a) Magnetic flux does not change through loop moving parallel to wire, so NO INDUCED CURRENT in loop a.

(b) B gets weaker as loop b moves away, so induced current tries to sustain B: ⊗ I induced

6. Is there a force between the two loops discussed in Question 5? If so, in what direction?

(7.) In what direction will the current flow in Fig. 29–9 if the rod moves to the left, which decreases the area of the loop to the left? USE LORENTZ FORCE!

(8.) Some modern stove burners are based on induction. That is, an ac current passes around a coil that is the "burner," a burner that never gets hot. Explain why it will heat a metal pan but not a glass container. no electric current

9. A region where no magnetic field is desired is surrounded by a sheet of low-resistivity metal. (*a*) Will this sheet shield the interior from a rapidly changing magnetic field outside? Explain. (*b*) Will it act as a shield to a static magnetic field? (*c*) What if the sheet is superconducting (resistivity = 0)?

(10.) Show, using Lenz's law, that the emf induced in the moving rod in Fig. 29–9 is positive at the bottom and negative at the top so that the current flows clockwise in the circuit loop on the left.

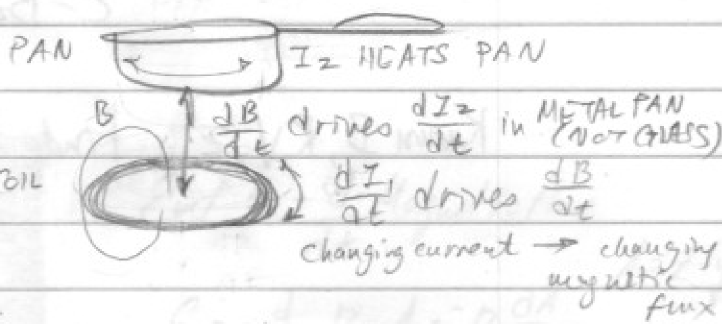
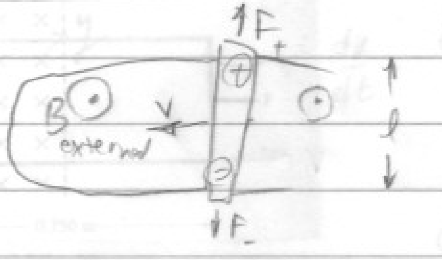


Fig 29-9



(7) $\vec{F} = q\vec{v} \times \vec{B}$ as drawn

So current flows

(10) Lenz's Law: Flux enclosed by loop DECREASES as loop area decreases → Induced Emf OPPOSES DECREASE by driving INDUCED B_{ind} of the SAME SIGN as $B_{external}$ ⊙

Need a CLOCKWISE current to do this (⊙B_{ind} ‖ ↑E $-\varepsilon$ $+\varepsilon$ ↓ ∇ Emf

Ch 29   P 3, 4, 7, 14

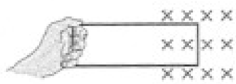


FIGURE 29–28 Problem 3.

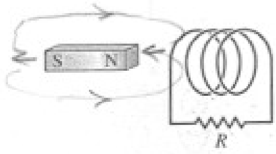


FIGURE 29–29 Problem 4.

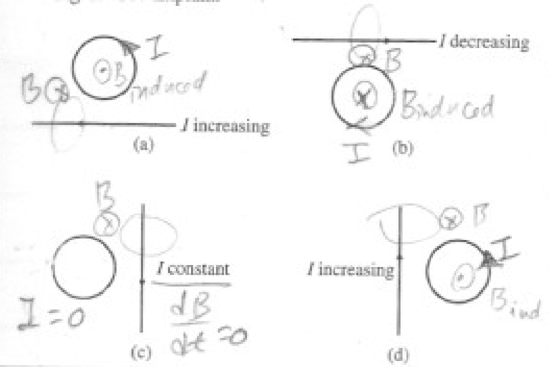
(3) (I) The rectangular loop shown in Fig. 29–28 is pushed into the magnetic field which points inward as shown. In what direction is the induced current? Explain.

ℰ opposes increase in B⊗

(4) (I) The north pole of the magnet in Fig. 29–29 is being inserted into the coil. In which direction is the induced current flowing through the resistor R? Explain.

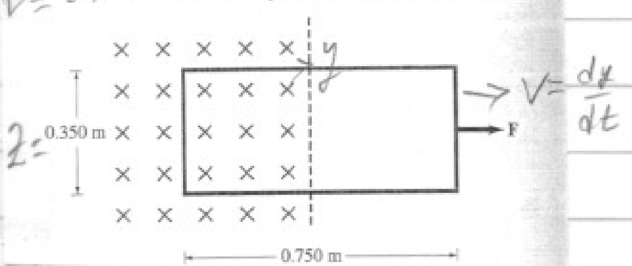
ℰ opposes decrease in B ←

(7) (II) What is the direction of the induced current in the circular loop due to the current shown in each part of Fig. 29–30? Explain.



(14.) (II) A single rectangular loop of wire with the dimensions shown in Fig. 29–33 is situated so that part is inside a region of uniform magnetic field of 0.450 T and part is outside the field. The total resistance of the loop is 0.230 Ω. Calculate the force required to pull the loop from the field (to the right) at a constant velocity of 3.40 m/s. Neglect gravity.

B =
R =
v =



$$Emf = -\frac{d}{dt}\,\text{Magnetic flux}$$

$$A = z \cdot y$$

$$\mathcal{E} = -\frac{d}{dt} B \cdot A = -B\frac{dA}{dt}$$

$$\frac{dA}{dt} = z \cdot \frac{dy}{dt}$$

$$\mathcal{E} = -Bz\frac{dy}{dt} = -Bzv \quad ①$$

② $V = IR = \mathcal{E}$ and $F = I\vec{l} \times \vec{B} = IzB$ ③ Combine these:

$IR = Bzv$ $\quad F = IzB = \left(\frac{Bzv}{R}\right) zB = (Bz)^2 \frac{v}{R}$

$I = Bzv/R$

$$F = \frac{(0.45\,T \times 0.35\,m)^2 \times 3.4\,m/s}{0.23\,\Omega} = \underline{0.37} \quad \left[\frac{Tm}{\Omega}\left(\frac{Tm^2}{s} = V\right) = Tm\left(\frac{V}{\Omega} = I\right) = N \checkmark\right]$$